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ABSTRACT

This is one of eighteen sets of individualized mathematics problems developed by the Oregon Vo-Tech Math Project. Each of these problem packages is organized around a mathematical topic and contains problems related to diverse vocations. Solutions are provided for all problems. Problems in this booklet require the computation of volumes of solids, and other related computations (density, surface area). Problems are drawn from seven vocational areas: construction, forest products, forestry, electronics, aviation mechanics, wood products, and wastewater technology. (SD)

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INDIVIDUALIZED
LEARNING
SYSTEMS

Individualized Math Problems in

Volume

Oregon Vo-Tech Mathematics Problem Sets

Retrieval - Dissemination Center
Oregon Board of Education
942 Lancaster Drive N.E.
Salem, Oregon 97310
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Individualized Learning Systems

MATHEMATICS

Volume

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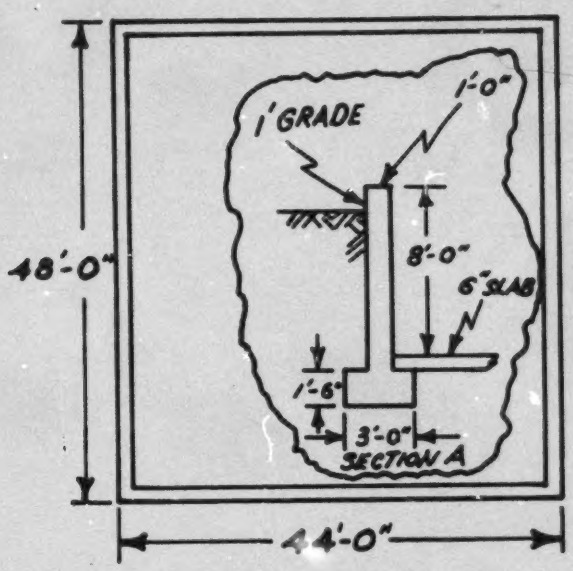
A. Problems with Solutions

1. The accompanying figure is a floor plan for a basement with section A the cross section of the footing, foundation wall and slab. Allow 5 feet on all sides for forming. At $1.75 per cubic yard, what is the cost of excavating?



Solution:

From the figure, the basement is 48' long, 44' wide and 9' deep. Since you must allow 5' on each side for forming, the length and width become 58' and 54' respectively. Then, the volume to be excavated is (58')(54')(9') = 28,188 cu ft.

Since the price is in $/cu yd, you must convert.
One cu yd is a cube 3 ft long, 3 ft wide and 3 ft deep. So,
1 cu yd is (3')(3')(3') = 27 cu ft.

The area to be excavated is then $\frac{28{,}188 \text{ cu ft}}{27 \text{ cu ft/cu yd}}$ = 1,044 cu yds

The price would then equal (1,044 cu yds)($1.75/cu yd) = $1,827

2. A customer ordered redimix concrete for his home. He wants to pour a slab 32 feet long, 17 feet wide and 4 inches deep. How many cubic yards of concrete does he need to do the job? If the concrete costs $20 per cubic yard, what would be his cost?

Solution:

Volume = (length)(width)(height)
= (32')(17')(1/3')
= 181.33 cu ft

A. Problems with Solutions (continued)

2. (continued)

Converting to cu yds = $\frac{181.33 \text{ } \cancel{\text{cu ft}}}{27 \text{ } \cancel{\text{cu ft}}/\text{cu yd}}$ = 6.72 cu yds

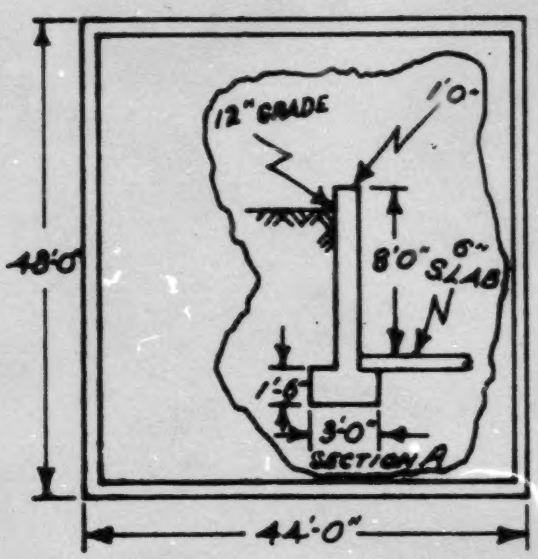
The price then is (6.72 ~~cu yds~~)($20/~~cu yd~~) = $134.32

Level 2

B. Problems without Solutions

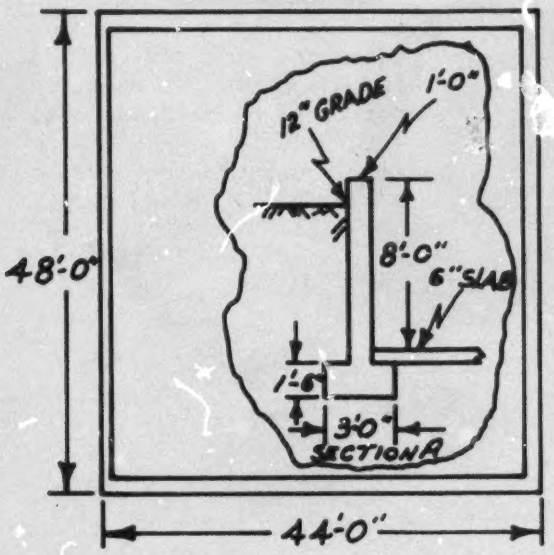
3. Find the cost of the slab in the figure if ready-mix costs $18.25 per cubic yard.

Note: The foundation is centered on the footing.

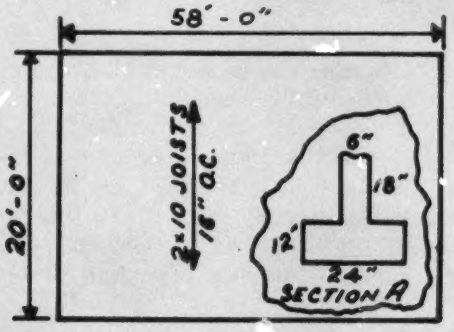


B. Problems without Solutions (continued)

4. At $19.75 per cubic yard, what would be the cost of ready-mix for the footing and foundation wall shown in the figure?
Note: Volume = (cross sectional area)(length).



5. How many cubic yards of concrete will there be in the footing foundation shown?



B. Problems without Solutions (continued)

6. John needs a new driveway for his house. The driveway is 10 feet wide by 75 feet long. He will need 4 inches of 1 1/2-0 crushed rock. Cost delivered and spread at $3.45 per cubic yard. Also, he will need a layer of 3/4-0 crushed rock on top 2 inches deep, delivered at a cost of $3.25 per yard. How many yards of 1 1/2-0 and 3/4-0 will he need, and what will be his total cost for the rock? If he pays cash, he is allowed to take a 2% discount. How much will he save if he pays cash?
Note: Crushed rock must be ordered in 1/4 cu yd intervals (i.e. 9 1/4, 9 1/2, 9 3/4 etc.).

7. John wants to build a new home and wants to know how much concrete he will need, and what it would cost for the material. The house size is 32 feet wide by 64 feet long. The footing that the foundation sets on is 18 inches wide by 6 inches high. The foundation is 6 inches wide by 24 inches high and requires 2,500 lbs concrete at a cost of $19.20 per cubic yard. The footing requires 2,000 lbs concrete at a cost of $18.40 per cubic yard. What is the total cost of concrete for this house?

B. Problems without Solutions (continued)

8. Find the cubic content of a tank with a 6 inch radius and a height of 4 feet. Give the result in cubic feet.
   Note: Area of a circle = πr^2

Complete Solutions to B Problems

3. Since the foundation is centered on the footing, the outside edge of the slab is two ft from the outermost point of the footing. Therefore, the slab measures 44' long by 40' wide. The volume equals (length)(width)(thickness)

Volume = (44')(40')(1/2') = 880 cu ft

Converting $\frac{880 \text{ cu ft}}{27 \text{ cu ft/cu yd}}$ = 32.59 cu yd

Cost: (32.59 cu yds)($18.25/cu yd) = $594.81

4. Total volume = (cross sectional area)(length)

Since area = (length)(width),

Cross sectional area = (area of footing) + (area of wall)

= (3')(1 1/2') + (1')(8 1/2')
= 4.5 sq ft + 8.5 sq ft
= 13 sq ft

The length of the foundation equals the perimeter minus the overlap.

So, length = 48' + 42' + 48' + 42' = 180 ft

Total volume = (13 sq ft)(180 ft) = 2,340 cu ft

Converting, $\frac{2{,}340 \text{ cu ft}}{27 \text{ cu ft/cu yd}}$ = 86 2/3 cu yds

Cost = (86 2/3 cu yds)($19.75/cu yd) = $1,711.67

5. Total volume = (cross sectional area)(length)

Cross sectional area = (area of footing) + (area of wall)

= (1')(2') + (1/2')(1 1/2')

= 2 sq ft + 0.75 sq ft

= 2.75 sq ft

Length equals perimeter minus overlap = 20' + 20' + 54' + 54'
= 148 feet

Volume = (2.75 sq ft)(148 ft) = 407 cu ft

Converting, $\frac{407 \text{ cu ft}}{27 \text{ cu ft/cu yd}}$ = 15.07 cu yds

Complete Solutions to B Problems (continued)

6. Volume = (length)(width)(thickness)

Volume of 1 1/2-0 crushed rock needed = (75')(10')(1/3') = 250 cu ft

Converting, $\frac{250 \text{ cu ft}}{27 \text{ cu ft/cu yd}}$ = 9.26 cu yds

So, 9 1/2 cu yds must be ordered

Cost = (9.5 cu yds)($3.45/cu yd) = $32.78

Volume of 3/4-0 crushed rock needed = (75')(10')(1/6') = 125 cu ft

Converting, $\frac{125 \text{ cu ft}}{27 \text{ cu ft/cu yd}}$ = 4.63 cu yds

So, 4 3/4 cu yds must be ordered

Cost = (4.75 cu yds)($3.25/cu yd) = $15.44

Total cost = $32.78 + $15.44 = $48.22

His discount for cash is 2% of $48.22 = ($48.22)(0.02) = $0.96

So, he would pay $48.22 - $0.96 = $47.26

7. Total cost = cost of footing + cost of foundation

Volume = (cross sectional area)(length)
Length = perimeter - overlap
= (32' - 3') + 64' + (32' - 3') + 64'
= 29' + 64' + 29' + 64'
= 186 ft

Cross sectional area of the footing = (height)(width)
= (1/2')(1 1/2') = 0.75 sq ft

Cross sectional area of the foundation = (height)(width)
= (2')(1/2') = 1 sq ft

Volume of footing = (0.75 sq ft)(186 ft) = 139.5 cu ft

Converting, $\frac{139.5 \text{ cu ft}}{27 \text{ cu ft/cu yd}}$ = 5.17 cu yds

Cost of footing = (5.17 cu yds)($18.40/cu yd) = $95.07

Volume of foundation = (1 sq ft)(186 ft) = 186 cu ft

Complete Solutions to B Problems (continued)

7. (continued)

Converting, $\frac{186 \text{ cu ft}}{27 \text{ cu ft/cu yd}} = 6.89$ cu yds

Cost of foundation = (6.89 cu yds)($19.20/cu yd) = $132.27

Total cost = $132.27 + $95.07 = $227.34

8. Volume of a cylinder = $(\pi)(\text{radius})^2(\text{height})$

Our cylinder has a radius of 0.5 ft and a height of 4 ft

Volume = $(\pi)(0.5 \text{ ft})^2(4 \text{ ft}) = (\pi)(0.25 \text{ sq ft})(4 \text{ ft})$

$= \pi$ cu ft

$\doteq 22/7$ cu ft

$= 3\ 1/7$ cu ft

A. Problems with Solutions

1. Calculate the approximate diameter inside the bark, d.i.b., from the following circumference measurements of standing trees. Assume that the trees are circular in cross section and the bark is 6 in thick. Round your answer to the nearest inch.

   a) Circumference = 12 ft 9 in b) Circumference = 11 ft 7 in

   Solution:

   a) 12 ft 9 in = 153 in

   $$\text{Diameter including bark} = \frac{\text{Circumference}}{\pi} = \frac{153 \text{ in}}{3.14}$$

   $$= 48.7 \text{ in}$$

   $$\text{d.i.b.} = (48.7 \text{ in} - 12 \text{ in}) = 36.7 \text{ in} = 37 \text{ in}$$

   b) 11 ft 7 in = 139 in

   $$\text{Diameter including bark} = \frac{\text{Circumference}}{\pi} = \frac{139 \text{ in}}{3.14}$$

   $$= 44.3 \text{ in}$$

   $$\text{d.i.b.} = (44.3 \text{ in} - 12 \text{ in}) = 32.3 \text{ in} = 32 \text{ in}$$

2. Complete the density and weight columns in the table below based on the data given for the various types of pulpwood. Use the following formulae:

   $$\text{Density, lb/cu ft} = (62.4)(\text{Sp Gravity})\left(1 + \frac{\% \text{ Moisture}}{100}\right)$$

   Solid Wood, lb/cord = (Solid Wood, cu ft/cord)(Density, lb/cu ft)

   Total Weight, lb/cord = Solid Wood, lb/cord + Bark, lb/cord

Species	Sp Gravity	Moisture (%)	Density (lb/ft)	Solid Wood (ft /cord)	Bark lb/cord	Solid Wood lb/cord	Total Weight lb/cord
Long leaf Pine	0.53	105	_____	72	650	_____	_____
Short leaf Pine	0.44	120	_____	72	500	_____	_____
Slash Pine	0.52	120	_____	72	500	_____	_____

Solution:

A. Problems with Solutions (continued)

2. Solution: (continued)

For Long Leaf Pine:

$$\text{Density} = (62.4)(0.53)\left(1 + \frac{105}{100}\right) = 67.8 \text{ lb/cu ft}$$

$$\text{Solid Wood} = (72 \text{ ~~cu ft~~/cord})(67.8 \text{ lb/~~cu ft~~})$$
$$= 4,881.6 \text{ lb/cord}$$

$$\text{Total Weight} = 4,881.6 \text{ lb/cord} + 650 \text{ lb/cord}$$
$$= 5,531.6 \text{ lb/cord}$$

For Short Leaf Pine:

$$\text{Density} = (62.4)(0.44)\left(1 + \frac{120}{100}\right) = 60.4 \text{ lb/cu ft}$$

$$\text{Solid Wood} = (72 \text{ ~~cu ft~~/cord})(60.4 \text{ lb/~~cu ft~~})$$
$$= 4,348.8 \text{ lb/cord}$$

$$\text{Total Weight} = 4,348.8 \text{ lb/cord} + 500 \text{ lb/cord}$$
$$= 4,848.8 \text{ lb/cord}$$

For Slash Pine:

$$\text{Density} = (62.4)(0.52)\left(1 + \frac{120}{100}\right) = 71.4 \text{ lb/cu ft}$$

$$\text{Solid Wood} = (72 \text{ ~~cu ft~~/cord})(71.4 \text{ lb/~~cu ft~~})$$
$$= 5,140.8 \text{ lb/cord}$$

$$\text{Total Weight} = 5,140.8 \text{ lb/cord} + 500 \text{ lb}$$
$$= 5,640.8 \text{ lb/cord}$$

B. Problems without Solutions

3. A dam tender opens a gate which is one foot high and three feet wide. He times a chip on the flowing water at 15 ft in 5 seconds. Assuming this is the average velocity of the water, how long (in hours, minutes, and seconds) should he leave the gate open for one acre foot of water to pass through?

B. Problems without Solutions (continued)

4. A round pond is 40 chains in diameter and averages 7 ft in depth. How many acre feet of water does it contain?
Note: 1 chain = 66 ft; 1 acre ft = 43,560 cubic feet

5. A circular tunnel 14 ft in diameter is cut through a mountain. The length of the tunnel is 5/6 mile. Determine the number of cubic yards of material removed.

6. A cone-shaped pile of woodchips is 240 ft in diameter at the base and 110 ft high.

   a) Determine the number of cubic feet of chips.

   b) A 'unit' of woodchips contains a volume of 200 cubic feet. Calculate the number of units of woodchips in the above pile.

B. Problems without Solutions (continued)

7. A total volume of 10,000 gallons of fuel is to be stored in cylindrical tanks which are 6 ft in diameter and 8 ft 4 in long. Determine the number of tanks required to store all of the fuel. There are 7.48 gallons per cubic foot.

8. From a knowledge of moisture content and specific gravity (based on ovendry weight and green volume) the weight per cubic foot of any species of pulpwood may be computed by the relationship:

$$\text{Density, lb/cu ft} = (\text{specific gravity})(62.4)\left(1 + \frac{\% \text{ moisture}}{100}\right)$$

If the solid wood volume of a cord of Loblolly Pine is 72 cu ft and the estimated bark weight is 700 lb per cord, compute the density and the total weight of a cord of Loblolly Pine pulpwood having a specific gravity of 0.46, a moisture content of 110%, solid wood volume per cord of 72 cu ft and an estimated bark weight of 700 lb per cord.

B. Problems without Solutions (continued)

9. A forester decides to 10% cruise an area in strips one chain wide. The total distance traveled during the sample is 230 lineal chains. The volume obtained by the sample is 225 MBF.

   Determine:
   a) The average volume per acre,
   b) The total volume of the tract based on the cruise,
   c) The total number of acres in the tract.

10. How many yards of rock are required to surface one mile (5,280 feet) of road to a depth of ten inches. The overall width of the rocked surface is 27 feet. Add 2.5% for loss of rock at the edges.

B. Problems without Solutions (continued)

11. In commercial scaling of logs of variable length, taper cannot be completely disregarded. A fixed taper rate of 1/2 in per 4 ft of length is often assumed for some species. Compute the volume of a 16 ft log whose small end diameter is 20 in by the following methods:
    a) Assume the log is a cylinder of 20 in d.i.b.
    b) Assume the log has a taper of 1/2 in per four feet of length and consider it as four separate cylinders of d.i.b. 20 in, 20.5 in, 21 in, and 21.5 in.

12. Determine the volume of water flowing through a culvert in gallons per minute during a heavy rain. The culvert is 18 inches in diameter and 30 feet long. Assume that it is 1/3 full at any instant and that the average velocity of water moving through the culvert is 3 feet per second. There are 7.48 gallons per cubic foot.

Complete Solutions to B Problems

3. 1 acre foot = 43,560 cu ft = (Velocity)(Time)(Area of gate)

$$\text{Time} = \frac{43{,}560 \text{ cu ft}}{(\text{Velocity})(\text{Area of gate})} = \frac{43{,}560 \text{ cu ft}}{(3 \text{ ft/sec})(1 \text{ ft})(3 \text{ ft})}$$

$$= \frac{43{,}560 \text{ } \cancel{\text{cu ft}}}{9 \text{ } \cancel{\text{cu ft}}/\text{sec}}$$

$$= 4{,}840 \text{ sec} = 1 \text{ hr } 20 \text{ min } 40 \text{ sec}$$

4. $\text{Volume in cu ft} = (\pi r^2)(\text{depth})$
$= (3.14)\left[(20 \text{ } \cancel{\text{chains}})(66 \text{ ft}/\cancel{\text{chain}})\right]^2 (7 \text{ ft})$
$= 38{,}317{,}377 \text{ cu ft}$

1 acre foot = 43,560 cu ft

$$\text{Volume in acre feet} = \frac{38{,}317{,}377 \text{ cu ft}}{43{,}560 \text{ cu ft/acre ft}} = 879.65 \text{ acre feet}$$

5. $\text{Volume} = (\pi r^2)(\text{length}) = (3.14)(7 \text{ ft})^2 (5{,}280 \text{ ft})(5/6)$
$= 677{,}327 \text{ cu ft}$

$$\text{Volume in cu yd} = \frac{\text{Volume, cu ft}}{27 \text{ cu ft/cu yd}} = \frac{677{,}327 \text{ } \cancel{\text{cu ft}}}{27 \text{ } \cancel{\text{cu ft}}/\text{cu yd}}$$

$$= 25{,}086.2 \text{ cu yd}$$

6. $\text{Volume} = (1/3)(\pi)(r^2)(h) = (1/3)(3.14)(120 \text{ ft})^2 (110 \text{ ft})$
$= 1{,}658{,}760.9 \text{ cu ft}$

$$\text{Volume in units} = \frac{\text{Volume in cu ft}}{200 \text{ cu ft/unit}}$$

$$= \frac{1{,}658{,}760.9 \text{ } \cancel{\text{cu ft}}}{200 \text{ } \cancel{\text{cu ft}}/\text{unit}} = 8{,}293.8 \text{ units}$$

7. $$\text{Volume of tank} = \frac{(\pi)(\text{Diameter})^2}{4} (\text{length})$$

$= (3.14)(6 \text{ ft})^2 (1/4)(25/3 \text{ ft})$
$= 235.6 \text{ cu ft}$

Volume of tank in gallons = (Volume in cu ft)(7.48 gal/cu ft)
$= (235.6 \text{ } \cancel{\text{cu ft}})(7.48 \text{ gal}/\cancel{\text{cu ft}})$
$= 1{,}762.3 \text{ gal}$

$$\text{Number of tanks} = \frac{\text{Total Volume}}{\text{Volume per tank}} = \frac{10{,}000 \text{ } \cancel{\text{gals}}}{1{,}762.3 \text{ } \cancel{\text{gal}}/\text{tank}}$$

$$= 5.68 \text{ tanks}$$

Use 6 tanks

8. Density = (0.46)(62.4 lb/cu ft)$\left(1 + \frac{110}{100}\right)$

= 60.3 lb/cu ft

Solid wood = (60.3 lb/~~cu ft~~)(72 ~~cu ft~~/cord) = 4,341.6 lb/cord

Adding the weight of the bark,

Weight = 4,341.6 lb/cord + 700 lb/cord = 5,041.6 lb/cord

9. Number of acres cruised = $\frac{(230 \text{ ch})(1 \text{ ch})}{10 \text{ sq ch/acre}} = \frac{230 \text{ ~~sq ch~~}}{10 \text{ ~~sq ch~~/acre}}$

= 23 acres

Average volume = $\frac{\text{Volume cruised}}{\text{Acres cruised}} = \frac{225 \text{ MBF}}{23 \text{ acres}}$ = 9.78 MBF/acre

Total Volume of Tract = (10)(Volume cruised)
= (10)(225 MBF)
= 2,250 MBF

Total Acres in the tract = (10)(Acres cruised)
= (10)(23 acres)
= 230 acres

10. $\frac{\text{Yards of rock}}{\text{Foot of road}} = \frac{(\text{length})(\text{width})(\text{thickness})}{27 \text{ cu ft/cu yd}}$

$= \frac{(1 \text{ ft})(27 \text{ ~~ft~~})(10/12 \text{ ~~ft~~})}{27 \text{ ~~cu ft~~/cu yd}}$ = 5/6 cu yd

Yards of rock/mile = (yards of rock/ft)(feet/mile)
= (5/6 cu yd/ft)(5,280 ft/mile)
= 4,400 cu ft/mile

Add 2.5% for losses,

Total amount = 4,400 cu yd + (2.5%)(4,400 cu yd)
= 4,400 cu yd + (0.025)(4,400 cu yd)
= 4,400 cu yd + 110 cu yd
= 4,510 cu yd

Complete Solutions to B Problems (continued)

11. (a) Volume in cu ft = $\frac{(\pi)(d^2)(\text{length})}{(4)(144 \text{ sq in/sq ft})}$

$= \frac{(\pi)(20 \text{ in})^2 (16 \text{ ft})}{(4)(144 \text{ sq in/sq ft})}$

$= \frac{(3.1416)(400 \text{ sq in})(16 \text{ ft})}{576 \text{ sq in/sq ft}}$

$= \frac{20{,}106.19 \text{ ft}}{576/\text{sq ft}} = 34.91 \text{ cu ft}$ or 35 cu ft

(b) Volume = (Basal area)(length)

Basal = $\frac{\pi(d^2)}{(4)(144 \text{ sq in/sq ft})}$

d.i.b.	
20.0	Volume = $\frac{(3.1416)(20.0 \text{ in})^2 (4 \text{ ft})}{(4)(144 \text{ sq in/sq ft})}$
	$= \frac{5{,}026.5482 \text{ sq in ft}}{576.0 \text{ sq in/sq ft}} = 8.7266 \text{ cu ft}$
20.5	Volume = $\frac{(3.1416)(20.5 \text{ in})^2 (4 \text{ ft})}{576 \text{ sq in/sq ft}}$
	$= \frac{5{,}281.0173 \text{ sq in ft}}{576 \text{ sq in/sq ft}} = 9.1684 \text{ cu ft}$
21.0	Volume = $\frac{(3.1416)(21 \text{ in})^2 (4 \text{ ft})}{576 \text{ sq in/sq ft}}$
	$= \frac{5{,}541.7694 \text{ sq in ft}}{576 \text{ sq in /sq ft}} = 9.6211 \text{ cu ft}$
21.5	Volume = $\frac{(3.1416)(21.5 \text{ in})^2 (4 \text{ ft})}{576 \text{ sq in/sq ft}}$
	$= \frac{5{,}808.8048 \text{ sq in ft}}{576 \text{ sq in/sq ft}} = 10.0847 \text{ cu ft}$

Total volume = 8.7266 cu ft + 9.1684 cu ft + 9.6211 cu ft + 10.0847 cu ft
= 37.6008 cu ft
or 38 cu ft

Complete Solutions to B Problems (continued)

12. Volume in cu ft/sec = (1/3)(cross-sectional area)(velocity)
= (1/3)(π)(r^2)(3 ft/sec)
= (1/3)(3.1416)(9/12 ft)^2 (3 ft/sec)
= 1.767 cu ft/sec

Volume in gal/sec = (1.767 ~~cu ft~~/sec)(7.48 gal/~~cu ft~~)
= 13.22 gal/sec

Volume in gal/min = (13.22 gal/~~sec~~)(60 ~~sec~~/min)
= 793.03 gal/min

VOLUME
Level II

Forestry

A. Problems with solutions.

1. Formulas: rectangular solid: $V = l\ w\ h$

right cylinder $V = \pi r^2 h$ $\pi = 3.1416$

conversions: 1 chain = 66 ft

43,560 cu ft = 1 acre-foot (water a depth of 1 ft on an acre)

1 gallon = 231 cu. in.

a) How many gallons of water are there in a cylinder tank 18 ft long and has a diameter of 6 feet?

b) How many acre-feet of water are there in a rectangular shaped pond which is 1 chain by 4 chains and is 4 feet deep?

c) How many acre- feet of water are there in a circular shaped lake whose diameter is 50 chains and has an average depth of 10 feet?

Solutions:

a) $V = \pi r^2 h = (3.1415)\left(\frac{6}{2}ft\right)^2 (18ft) = 508.93$ cu ft

$(508.93\ cuft)\left(\frac{12^3\ cu.\ in}{cu\ ft.}\right)\left(\frac{1\ gal}{231\ cu\ in}\right) = 3807$ gallons

b) 1 chain = 66 ft
(4ch)(66ft/ch) = 264 ft
$V = lwh = (264ft)\ (66ft)\ (4ft) = 69{,}696$ cuft.
$(69{,}696\ cu\ ft)\left(\frac{1\ acre-\ ft}{43560\ cuft}\right) = 1.6$ acre ft.

c) (50 ch) (66ft/ch)= 3300ft.

$v = \pi r^2 h = (3.1416)\left(\frac{3300ft}{2}\right)\ (10ft) = 85{,}530{,}060$ cu ft

$(85{,}530{,}060\ cuft)\ \left(\frac{1\ acre\ ft}{43560 cuft}\right) = 1964$ acre ft.

A. Problems with solutions, continued.

2. a) A stack of wood chips which is stored for paper manufacturing is in the shape of a cone. (volume of cone = $\frac{1}{3}\pi r^2 h$). If the stack is 100 ft high and has a diameter of 250 ft determine the number of cubic feet of chips in the stack.

   b) If a cord of chips is considered 200 cu.ft how many cords of chips are there in the stack?

Solutions:

a) $r = \frac{d}{2} = \frac{250}{2} = 125$ ft.

$$V = \frac{1}{3}\pi r^2 h = \frac{1}{3}\,(3.1416)\,(125\text{ft})^2\,(100\text{ft})$$

$V = 1{,}636{,}250$ cu.ft.

b) $(1{,}636{,}250\,\text{cu ft})\left(\frac{1\text{ cord}}{200\text{ cu ft}}\right) = 8181.25$ cords

B. Problems without solutions.

3. In metric measure finished lumber is measured in m^3 (cubic meters) while the most common unit is the board-foot. If a board-foot has dimensions 12in by 12in by 1 in and 39.37 in = 1 m, represent 1 cubic meter in board-feet.

4. A standard cord of wood is a pile made up of stacked sticks that is 8 ft. long, 4ft high and 4 feet wide.

a) How many cubic feet of space is taken up by a cord of wood?

b) How many cords would you estimate to be in a stack 10ft long, 6 feet high and 8 feet wide?

c) In the space taken up by a cord of wood it is estimated that 22 to 33% of the space is not solid wood but actually air space between sticks. What is the actual number of cubic feet of solid wood to be expected in a cord of wood?

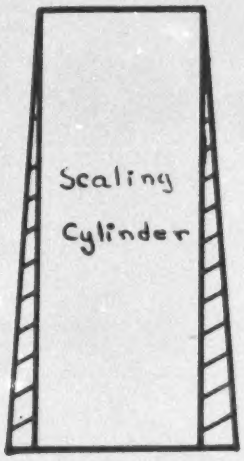
B. Problems without solutions, continued.

5. Although a log does not form a true cylinder, a common method of determining the volume is to assume that the log is a cylinder (using the diameter of the small end) and that the rest is waste.

Using this method and the volume of a cylinder given by $V = \pi r^2 h$ determine the volume (cu in and cu ft) of the following: (diameters given are at small end).

a) diameter 12 in, length 16 ft.

b) diameter 27 in, length 32 ft.



Complete solutions to B problems.

3. Solution :

$1\ m^3 = (1m)\ (1m)\ (1m) = (39.37in)\ (39.37in)(39.37in) = 61{,}023$ cu in

1 bd ft = (12in)(12in) (1 in)= 144 cu. in.

so,

$$1\ m^3 = (61023\ cuin)\ \frac{1\ bd.ft}{144\ cuin} = 424\ bdft.$$

4. Solution:

a) V = lwh = (8ft)(4ft)(4ft) = 128 cu ft

b) V = lwh = (10ft)(6ft)(8ft) = 480 cuft

$$(480\ cuft)\left(\frac{1\ cord}{128\ cuft}\right) = 3.75\ cords$$

c) Since 22% to 33% is waste, between 100% - 33% = 67% and 100% - 22% = 78% would be solid wood. Then we could expect between $(0.67)(128\ ft)^3 = 86$ cu ft and $(0.78)(128\ ft)^3 = 100$ cu ft of actual solid wood.

Complete solutions to B problems, continued.

5. Solution:

a) $r = \frac{12in}{2} = 6$ in $\qquad h = (16\cancel{ft})\left(\frac{12in}{\cancel{ft}}\right) = 192$ in

$V = \pi r^2 h = (3.1416)\ (6in)^2\ (192in) = 21{,}715$ cu in.

$V = (21{,}715\ \cancel{cu\ in})\left(\frac{1\ cu\ ft}{1728\ \cancel{cu\ in}}\right) = 12.56$ cu. ft.

b) $r = \frac{27in}{2} = 13.5$ in $\qquad h = (32ft)\left(\frac{12in}{\cancel{ft}}\right) = 384$ in

$V = \pi r^2 h = (3.1416)\ (13.5in)^2\ (384$ in)

$V = 219{,}861$ cu. in

$V = 219{,}861\ \cancel{cu\ in}\left(\frac{1\ cu\ ft}{1{,}728\ \cancel{cu\ in}}\right) = 127.23$ cu.ft.

VOLUME
Level I

B. Problems without solutions.

1. You are fabricating a recorder console using a Bud standard two-door cabinet with inside dimensions of 45"h x 21"w x 17"d. Two recorder racks are to be installed in the cabinet with equal dimensions of 8 1/2"h x 19"w x 15"d. Engineering specifications require that the net air volume within the cabinet be replaced with a blower every 15 seconds. What fan capacity in CFM (cubic feet per minute) would be the minimum required?

Complete solutions to B problems.

1. a. Compute overall cabinet air volume. Convert to FT .

   V = 45 x 21 x 17 = 16,065 in = 9.3 Ft

   b. Compute total colume occupied by the two racks. Convert to Ft .

   V = 2(8 1/2 x 19 x 15) = 4845 in = 2.8 Ft

   c. Find net volume of air in the cabinet.

   V = 9.3 -2.8 - 6.5 Ft

   d. Find rate of air movement:

   6.5 Ft per 15 sec = 4 x 6.5 Ft per min. = 26 Ft /min

   Fan capacity = 26 CFM (minimum)

B. Problems without Solutions

1. Compute the piston displacement of a radial engine having nine cylinders, a bore of 5 in, and a stroke of 5 in.

2. If the bore is 6 inches and the stroke is 6 inches, what is the piston displacement?

Complete Solutions to B Problems

1. The displacement for one cylinder must be multiplied by the number of cylinders.

Displacement for one cylinder = $(\pi)(r)^2(h)$
$= (3.14)(2.5 \text{ in})^2(5 \text{ in})$
$= 98.13 \text{ cu in}$

Times the number of cylinders = $(9)(98.13 \text{ cu in})$
$= 883.13 \text{ cu in}$

2. Displacement is found by multiplying cross-sectional area of cylinder by distance piston moves during one stroke. Area formulas are $A = 1/4 \pi D^2$ or $A = \pi r^2$ where D is the diameter and r is the radius.

Displacement = $(\pi)(r^2)(6)$

$= (3.14)(3 \text{ in})^2(6 \text{ in})$

$= 169.56 \text{ cu in}$

VOLUME
Level II

Wood Products

A. Problems with solutions.

1. Find the weight of SO_2 gas, in tons per day, which flows through a 6 inch pipe at a flow velocity of 90 feet per second. A volume of 359 cubic feet contains 64 pounds of SO_2.

$$\text{Weight} = (\text{velocity})\left(\frac{\text{seconds}}{\text{per day}}\right)\left(\frac{\text{Cross section}}{\text{area of pipe}}\right)\left(\frac{64 \text{ lbs. of } SO_2}{359 \text{ cu. ft.}}\right)\left(\frac{1 \text{ ton}}{2000 \text{ lbs}}\right)$$

Note: Area of a circle = πr^2 $\pi = 3.14$

Accuracy : Round the weight to the nearest hundredth of a ton.

Definitions: SO_2 - sulpher dioxide gas.

Solution: Substituting into the equation

$$\text{Weight} = \left(90\frac{\text{ft}}{\text{sec}}\right)\left(86{,}400\ \frac{\text{sec}}{\text{day}}\right)(3.14)(.25\ \text{ft})^2\left(\frac{64 \text{ lbs}}{359 \text{ cu. ft}}\right)\left(\frac{1 \text{ ton}}{2000 \text{ lbs}}\right)$$

$$= 136.03 \text{ tons/day}$$

B. Problems without solutions.

2. Water from the blow pits is pumped into a sewer as a first step in removing water from wood fiber pulp and 1 O.D. gram of wood fiber is lost per liter of water discharged. Find the O.D. tons per day of fiber loss for a discharge of 5,500,000 gallons per day.

$$\text{O.D. tons per day} = (\text{discharge})\left(\frac{4.4048 \text{ liters}}{\text{gallon}}\right)\left(\frac{\text{fiber loss}}{\text{liter}}\right)\left(\frac{.0353 \text{ oz.}}{\text{gram}}\right)\left(\frac{1 \text{ ton}}{32{,}000 \text{ oz.}}\right)$$

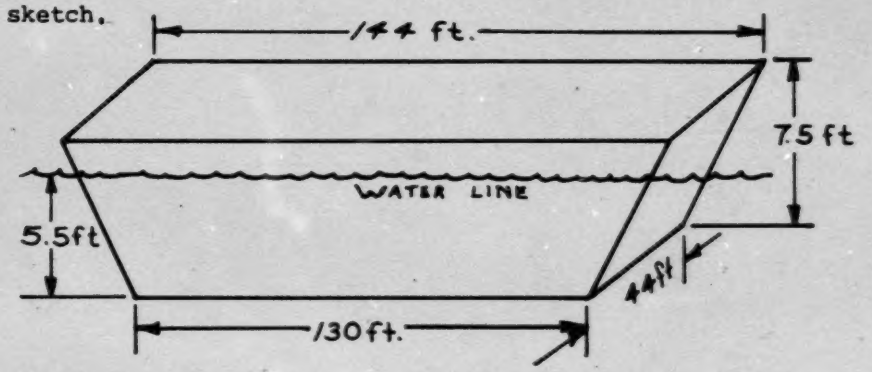
Accuracy : Round the O. D. tons to the nearest hundredth

Definitions : Blow pits - tanks where wood fibers are separated from each other.

O.D. - oven dried wood pulp unit description.

B. Problems without solutions.

3. Wood chips are delivered to a mill on a barge having dimensions as indicated in this sketch.



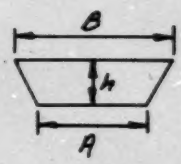
The barge displaces an amount of salt water which has a weight equal to the barge and chips. Specific gravity of salt water is 1.06, one gallon of fresh water weight 8.34 pounds, and 1 cubic foot of water contains 7.34 gallons. The barge weight is 25 tons. Find the tons of chips on the barge when the water level is 2 feet below the top edge of the barge.

$$\text{Tons} = \left(\frac{8.34 \text{ lbs}}{\text{gallon}}\right)\left(\text{specific gravity}\right)\left(\frac{7.34 \text{ gals}}{\text{cu ft}}\right)\left(\text{area of barge side below water}\right)\left(\text{barge width}\right)\left(\frac{1 \text{ ton}}{2000 \text{ lbs}}\right) - 25 \text{ tons}$$

Accuracy: Round to the nearest tenth of a ton.

Definitions: Specific gravity - ratio of solution weight to weight of distilled water

Note: Area of a trapezoid = $\left(\frac{A + B}{2}\right)(h)$



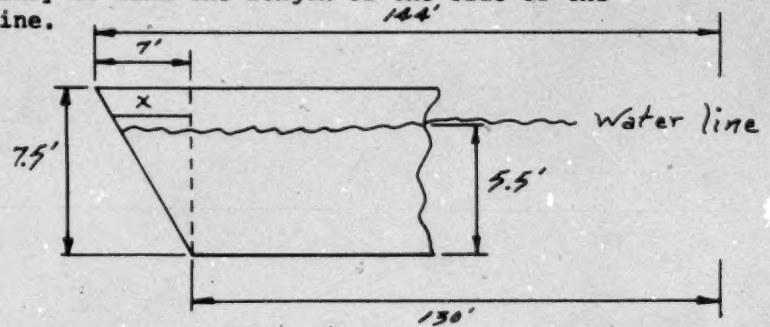
Complete solution to B problems.

2. Substituting into the equation.

$$\text{O.D. tons} = \left(5{,}500{,}000 \frac{\text{gallons}}{\text{day}}\right)\left(\frac{4.4048 \text{ liters}}{\text{gallon}}\right)\left(\frac{1 \text{ O.D. gram}}{\text{liter}}\right)\left(\frac{.0353 \text{ oz}}{\text{gram}}\right)\left(\frac{1 \text{ ton}}{32{,}000 \text{ oz}}\right)$$

$$= 26.72 \text{ tons/day}$$

3. First it is necessary to find the length of the side of the barge at the water line.



In the drawing, solve for x by use of similar triangles.

$$\frac{7.5'}{5.5'} = \frac{7.0'}{x}$$

$$(7.5')\ (x) = (5.5')\ (7.0')$$

$$x = \frac{(5.5')\ (7.0')}{7.5'}$$

$$x = 5.133'$$

Therefore, the length of the top of the trapezoid is:

$$130' + 2(5.133')$$

$$= 130' + 10.266'$$

$$= 140.266'$$

$$\text{Area of the trapezoid} = \left(\frac{140.266' + 130'}{2}\right)(5.5')$$

$$= 743.23 \text{ sq. ft.}$$

Complete solutions to B problems.

3. continued.

$$\text{tons of chips} = \left(\frac{8.34\ \cancel{\text{lbs}}}{\cancel{\text{gallon}}}\right)(1.06)\left(\frac{7.34\ \cancel{\text{gallons}}}{\cancel{\text{cu ft}}}\right)(743.23\ \cancel{\text{sq ft}})(44\text{ft})\left(\frac{1\text{ ton}}{2000\text{lbs}}\right)$$

$$- 25 \text{ tons} = 1036 \text{ tons}$$

A. Problems with Solutions

1. In the construction of a circular trickling filter, 55 feet in diameter, a large quantity of rock is required. Just how many yards of rock will be required if the average rock depth is to be 7 feet 4 inches?

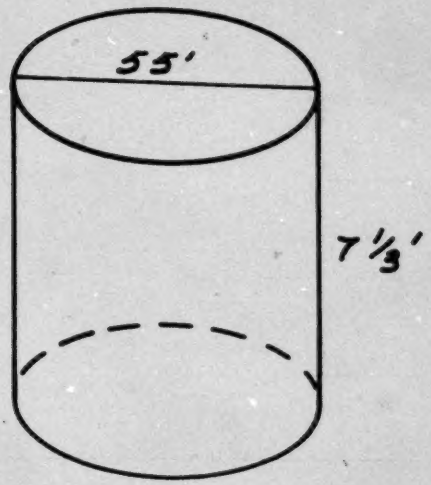
Solution:

This problem is an application of the volume of a cylinder. The formula V = b h will be applied where b = the area of the base and h = height of the cylinder. Most mathematicians will want to use $A = \pi r^2$ for the area of the circular base, but most STP people use A = 0.7854d which involves fewer settings on a sliderule.

Area of the base = (55') (0.7854) = 2,375.84 sq ft

Volume of the cylinder = (7.3 ft)(2,375.84 sq ft) = 17,422.83 cu ft

Converting (17,422.83 ~~cu ft~~)(1 cu yd/27 ~~cu ft~~) = 645.29 cu yds



A. Problems with Solutions (continued)

2. The piston of a plunger type pump is 10 inches in diameter and has an effective stroke of 5 inches. How many gallons per day does it pump if it operates at 45 strokes per minute?

Solution:

$$\text{Each stroke moves } (10\ \cancel{\text{in}})^2\ (0.7854)\left(\frac{5\ \cancel{\text{in}}}{1{,}728\ \text{cu}\ \cancel{\text{in}}/\text{cu ft}}\right)$$

$$= 0.2273 \text{ cu ft}$$

$$\text{The pump makes } (45 \text{ strokes}/\cancel{\text{min}})(60\ \cancel{\text{min}}/\cancel{\text{hr}})(24\ \cancel{\text{hr}}/\text{day})$$
$$= 64{,}800 \text{ strokes/day}$$

There are 7.48 gallons/cu ft

$$\text{Pump moves} = (0.2273\ \cancel{\text{cu ft}})(7.48 \text{ gal}/\cancel{\text{cu ft}})(64{,}800 \text{ strokes/day})$$
$$= 110{,}173.22 \text{ gal/day}$$

3. A sealed lagoon (the bottom and sides have been treated to prevent seepage) is filled at the rate of 0.6 MGD. If the surface area of the lagoon is 5 acres and the evaporation rate is estimated at 0.2 inches per day, how much effluent is discharged to maintain a constant level in the lagoon?

Solution:

1 acre = 43,560 sq ft 0.2 inch = 0.016 ft

$$(43{,}560 \text{ sq ft}/\cancel{\text{acre}})(0.016 \text{ ft})(5\ \cancel{\text{acres}}) = 3{,}630 \text{ cu ft/day evaporation loss}$$

(MGD)(1.55) = cfs

$$1 \text{ day} = (60\ \cancel{\text{sec}}/\cancel{\text{min}})(60\ \cancel{\text{min}}/\cancel{\text{hr}})(24\ \cancel{\text{hr}}/\text{day}) = 86{,}400 \text{ sec/day}$$
$$(0.6 \text{ MGD})(1.55)(86{,}400 \text{ sec/day}) = 80{,}352 \text{ cu ft/day}$$

80,352 cu ft/day - 3,630 cu ft/day = 76,722 cu ft/day

$$(76{,}722\ \cancel{\text{cu ft}}/\text{day})(7.48 \text{ gal}/\cancel{\text{cu ft}}) = 573{,}880.56$$

B. Problems without Solutions

4. A newly established treatment plant in a small town has a 60 foot-by 15 foot-settling tank that is 9 feet deep. If we assume an average flow of 0.5 MGD, what is the detention time?

5. The sludge at the influent end of a settling tank is 26 inches deep and gradually lessens until there is-for all practical purpose-none at the effluent end of the tank. If the tank is 30 feet by 60 feet and 8 deet deep, how many gallons of sludge are in the tank?

6. The primary settling tank in a small installation is a circular tank 55 feet in diameter and has an average depth of 9.5 feet. If the average flow of sewage is 0.75 MGD, what is the detention time?

B. Problems without Solutions (continued)

7. What is the detention time in a digester which is 28 feet deep at the center, 22 feet at the sidewall, and 40 feet in diameter if 6,000 gallons of fresh sludge are pumped per day?

8. The detention time in a primary settling tank is 3 hours 22 minutes. If the tank is a circular tank 45 feet in diameter and 8 feet deep, what is the flow into the tank?

B. Problems without Solutions (continued)

9. You are filling a digester with raw sewage before starting. The digester has a capacity of 6,000 cubic feet, and the sewage is being pumped into it at the rate of 100 gallons per minute. How long will it take to fill the digester?

10. An aeration tank in an activated sludge plant is required to hold a mixed liquor (1.38 MGD plus a 20 percent sludge return) for six hours. Allowing a 20 percent buffer for peak run periods, what must be the dimensions of the tank if the width is to be 1/3 of the length? The tank is 13 feet 9 inches deep.

B. Problems without Solutions (continued)

11. You have two drying beds each being 60 feet long and 20 feet wide into which you wish to empty a circular digester 25 feet in diameter and 20 feet deep. If you fill both beds to a depth of 15 inches, how far will the level of the digester be lowered (in inches)?

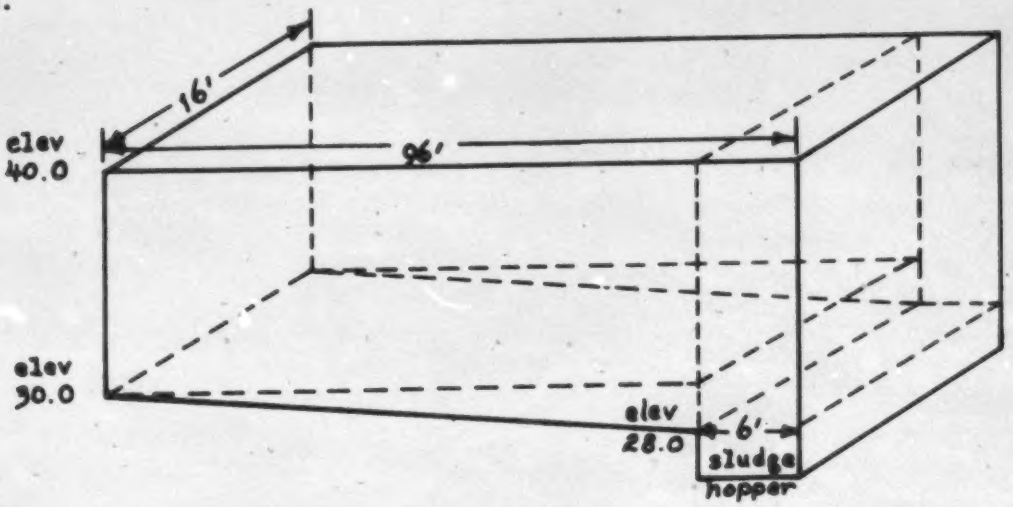
12. As detention time is a much calculated item, many operators like to be able to merely read the flow meter into the primary tank in terms of detention times instead of MGD. This is a simple process as the only variable involved is the flow. Assume you have a circular tank 45 feet in diameter and it has an average depth of 9 feet. Using this data derive a factor which will convert MGD to detention time. Then, use that factor to determine detention times for

    (a) 1.87 MGD

    (b) 2.463 MGD

B. Problems without Solutions (continued)

13.

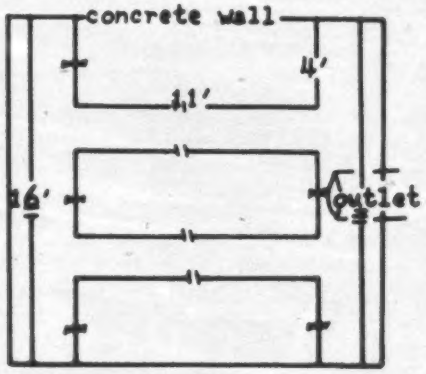


(a) The drawing above represents a rectangular primary sedimentation tank. The drawing is not to scale and would not include the dotted lines in a problem situation.

What is the volume of the tank in cubic feet, excluding the sludge hopper?

(b) Assuming an average daily flow of 1.5 MGD, what is the detention time of the tank?

(c) A diagram of the weir for the primary sedimentation tank appears below. What is the total weir length?



B. Problems without Solutions (continued)

13. (continued)

(d) With a 1.5 MGD daily flow into the sedimentation tank, what is the weir overflow rate?

(e) What is the surface area of the sedimentation tank?

What is the surface settling rate for a flow of 1.5 MGD?

Complete Solutions to B Problems

4. Detention time is the time required to displace the volume of a tank. For calculation, this is merely volume/flow.

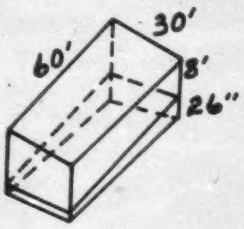
0.5 MGD = (1.55)(0.5 cu ft/~~sec~~)(60 ~~sec~~/~~min~~)(60 ~~min~~/hr)

= 2,790 cu ft/hr

(Note: (MGD)(1.55) = cu ft/sec)

The volume of the tank is (60')(15')(9') = 8,100 cu ft
Detention time is (8100 cu ft)/(2790 ft/hr) = 2.9 hrs

5. The sludge is in a triangular wedge. We will apply the usual formula and then multiply by 7.5 as there are 7.48 gallons per cubic foot.



V = 1/2 (l w h)
V = (1/2)(13/6 ft)(60 ft)(30 ft) = 1,950 cu ft

Convert cubic feet to gallons
(1,950 ~~cu ft~~)(7.5 gal/~~cu ft~~) = 14,625 gallons

6. Detention time is calculated by dividing the volume of the tank by the flow into the tank.

(MGD)(1.55) = cubic feet per second, so,
(MGD)(1.55)(60) = cubic feet per minute, and
(MGD)(1.55)(3600) = cubic feet per hour

The volume of the tank is calculated by the formula
$V = (0.7854)(D^1)(h)$

$$\text{Detention time} = \frac{(0.7854)(55\text{ ft})(55\text{ ft})(9.5\text{ ft})}{(0.75)(1.55\text{ cu ft/hr})(3{,}600)}$$

$$= \frac{22{,}570.432\ \text{~~cu ft~~}}{4{,}185\ \text{~~cu ft~~/hr}} = 5.39\text{ hr}$$

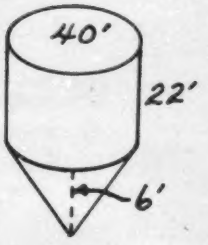
Complete Solutions to B Problems (continued)

7. There are at least two methods of solution to this problem. We can find the volume of the cylindrical portion of the digester and then add the volume of the cone. Or, realizing that the volume of a cone is one-third the volume of a cylinder just as high is the same as saying that the volume of the cone is the same as a cylinder one-third as tall, (all diameters being equal of course), we say that the cone 6 feet deep is the same as making the cylinder 2 feet deeper.

Volume of digester = (40 ft)(40 ft)(0.7854)(24 ft)
= 30,159.36 cu ft

$$\text{Detention time} = \frac{(30{,}159.36 \text{ cu ft})(7.5 \text{ gals/cu ft})}{6{,}000 \text{ gals/day}} = 37.7$$

or



$V = \pi r^2 h + 1/3 \pi r^2 h$
$V = \pi (20)^2 (22) + (1/3)\pi (20)^2 (6)$
$V = 27{,}646.08 \text{ cu ft} + 2{,}513.28 \text{ cu ft}$

$$\text{Detention time} = \frac{(30{,}159.36 \text{ cu ft})(7.5 \text{ gals/cu ft})}{6{,}000 \text{ gals/day}}$$

= 37.7 days

8. As detention time is Volume/flow (where flow is in cubic feet per hour) we have the formula

$$t = \frac{\text{Volume}}{\text{flow}}$$

Using the properties learned in ratios and proportions we know that flow = Volume/time. However, this solution will be in cubic feet per hour and it is standard practice to state flow in MGD.

Calculate cu ft per hour: $\frac{(45 \text{ ft})(45 \text{ ft})(0.7854)(8 \text{ ft})}{3.366 \text{ hr}} = 3{,}780 \text{ cu ft/hr}$

Convert to MGD: $\frac{(3{,}780 \text{ cu ft/hr})(7.5 \text{ gal/cu ft})(24 \text{ hr/day})}{1{,}000{,}000 \text{ gal/MG}} = 0.68 \text{ MGD}$

9. Convert 100 GPM to cubic feet per hour

$$\frac{(100 \text{ gal/min})(60 \text{ min/hr})}{7.48 \text{ gal/cu ft}} = 802 \text{ cu ft/hr}$$

$$\text{Fill} = \frac{6{,}000 \text{ cu ft}}{802 \text{ cu ft/hr}} = 7.48 \text{ hrs}$$

Complete Solutions to B Problems (continued)

10. We must first calculate the volume needed at peak flow.
The normal flow into the tank is 1.38 + 0.2(1.38) = 1.656 MGD
Peak flow would then be 120% of 1.656 MGD
(1.656)(1.2) = 1.9872 MGD

1 MGD = 41,440 GPH 7.48 gal = 1 cu ft

$$\text{Flow} = \frac{(1.9872\ \cancel{\text{MGD}})(41{,}440\ \cancel{\text{GPH/MGD}})}{7.48\ \cancel{\text{gal}}/\text{cu ft}} = 11{,}009.3 \text{ cu ft/hr}$$

Total volume = (11,009.3 cu ft/~~hr~~)(6 ~~hrs~~) = 66,055.8 cu ft

$$\text{Surface area} = \frac{66{,}055.8 \text{ cu ft}}{13.75 \text{ ft}} = 4{,}804.0581 \text{ sq ft}$$

4,804.0581 sq ft = (length)(width) = (L)(0.3333L) = 0.3333L

$$L^2 = \frac{4{,}804.0581 \text{ sq ft}}{0.3333} = 14{,}413.615 \text{ sq ft}$$

$$L = \sqrt{14{,}413.615 \text{ sq ft}} = 120.05 \text{ ft}$$

L/3 = 40.016 ft

Dimensions: 120 ft by 40 ft

11. The volume of the drying beds is (2)(60 ft)(20 ft)(1.25 ft)=3000 cu ft

To draw 3000 cubic feet from the digester, you must find the height of a cylinder 25 feet in diameter that has a volume of 3,000.

Volume of a cylinder = (0.25)(D)(h) = (0.7854)D h

$$\text{Hence, h (in feet)} = \frac{\text{Volume}}{(0.7854)D}$$

$$\text{h (in inches)} = \frac{(\text{volume})(12 \text{ in/ft})}{(0.7854)(25')(25')}$$

$$= \frac{(3000\ \cancel{\text{cu ft}})(12 \text{ in}/\cancel{\text{ft}})}{(0.7854)(25\ \cancel{\text{ft}})(25\ \cancel{\text{ft}})}$$

$$= 73.34 \text{ in}$$

Complete Solutions to B Problems (continued)

12. Detention time = volume of tank(cu ft)/flow(cu ft/hr)
$= \pi r^2 h/(\text{MGD})(1.55)(3600 \text{ sec/hr})$
$= (3.14)(22.5 \text{ ft})^2 (9 \text{ ft})/(\text{MGD})(1.55)(3600 \text{ sec/hr})$
$= (14{,}306.63 \text{ cu ft})/(5580 \text{ cu ft/hr})(\text{MGD})$
$= 2.56 \text{ hrs/MGD}$

(a) $(2.56 \text{ hrs/MGD})(1.87 \text{ MGD}) = 4.78 \text{ hrs}$

(b) $(2.56 \text{ hrs/MGD})(2.463 \text{ MGD}) = 6.31 \text{ hrs}$

13. (a) The tank may be visualized as a combination of three geometric solids: a main rectangular prism, an end rectangular prism, and a bottom triangular prism.

The main rectangular prism is:
$(96' - 6')(40.0' - 30.0')(16') = 14{,}400 \text{ cu ft}$

The end rectangular prism is:
$(6')(40.0' - 28.0')(16') = 1{,}152 \text{ cu ft}$

The bottom triangular prism is:
$\left[\frac{(96' - 6') \times 2}{2}\right](16') = 1440 \text{ cu ft}$

The total volume is: $14{,}400 + 1{,}152 + 1{,}440 = 16{,}992 \text{ cu ft} \cong 17{,}000 \text{ cu ft}$

(b) Detention time = (volume/flow)(7.5 gals/cu ft)(24 hrs/day)
$= \left(\frac{17{,}000 \text{ cu ft}}{1{,}500{,}000 \text{ gal/day}}\right)(7.5 \text{ gals/cu ft})(24 \text{ hrs/day})$
$= 2.04 \text{ hrs}$

(c) Weir length = (6)(4 ft) + (4)(11 ft) + (2)(16 ft)
= 24 ft + 44 ft + 32 ft = 100 ft

(d) Weir overflow rate = flow/lineal feet of weir

$$= \frac{1.5 \text{ MGD}}{100 \text{ ft}} = \frac{15{,}000 \text{ gals/day}}{\text{ft}}$$

(e) Surface area = (length)(width)
= (96 ft)(16 ft) = 1,536 sq ft

Surface settling rate = flow/surface area

$$= \frac{1.5 \text{ MGD}}{1{,}536 \text{ sq ft}} = \frac{976 \text{ gals/day}}{\text{sq ft}}$$